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## X.

## TELESCOPIC SEARCH FOR THE TRANS-NEPTUNIAN PLANET.

BY DAVID P. TODD, M. A.

Communicated June 10, 1885.

IN the twentieth volume of the American Journal of Science, at page 225, I gave a preliminary account of my search, theoretic and practical, for the trans-Neptunian planet. I say *the* trans-Neptunian planet, because I regard the evidence of its existence as well founded, and further, because, since the time when I was engaged upon this search, nothing has in the least weakened my entire conviction as to its existence in about that part of the sky assigned; while, as is well known, the independent researches in cometary perturbations by Professor Forbes conducted him to a result identical with my own, — a coincidence not to be lightly set aside as pure accident.

That five years have elapsed since this coincidence was remarked, and the planet is still unfound, is not sufficient assurance to me that its existence is merely fanciful. In so far as I am informed, this spot of the sky has received very little scrutiny with telescopes competent to such a search; and most observers finding nothing would, I suspect, prefer not to announce their ineffective search.

The time has now come when this search can be profitably undertaken by any observer having the rare combination of time, enthusiasm, and the necessary appliances. Strongly marked developments in astronomical photography have been effected since this optical search was conducted; and the capacity of the modern dry-plate for the registry of the light of very faint stars makes the application of this method the shortest and surest way of detecting any such object. Nor is this purely an opinion of my own. But the required apparatus would be costly; and the instrument, together with the services of an astronomer and a photographer, would, for the time being, be necessarily devoted exclusively to the work. While, however, the photographic search might have to be ended with a negative result, in so far as the trans-Neptunian planet is concerned, there would still remain the series of

photographic maps of the region explored, and these would be of incalculable service in the astronomy of the future.

In the latter part of the paper alluded to above, I state the speculative basis upon which I restricted the stellar region to be examined; also the fact that between November of 1877 and March of 1878 I was engaged in a telescopic scrutiny of this region, employing the twenty-six inch refractor of the Naval Observatory. For the purposes contemplated, I had no hesitation in adopting the method of search whereby I expected to detect the planet by the contrast of its disc and light with the appearance of an average star of about the thirteenth magnitude. A power of six hundred diameters was often employed, but the field of view of this eyepiece was so restricted that a power of four hundred diameters had to be used most of the time. I say, too, that, "after the first few nights, I was surprised at the readiness with which my eye detected any variation from the average appearance of a star of a given faint magnitude: as a consequence whereof my observing-book contains a large stock of memoranda of suspected objects. My general plan with these was to observe with a sufficient degree of accuracy the position of all suspected objects. On the succeeding night of observation they were re-observed; and, at an interval of several weeks thereafter, the observation was again verified." Subjoined to the original observations are printed these verifications in heavy-faced type.

In conducting the search, the plans were several times varied in slight detail, — generally because experience with the work enabled me to make improvements in method. Usually I prepared every few days a new zone-chart of the region over which I was about to search; and these charts, while containing memoranda of all the instrumental data which could be prepared beforehand, were likewise so adjusted with reference to the opposition-time of the planet as to avoid, if possible, its stationary point. The same thing, too, was kept in mind in selecting the times of subsequent observation. Notwithstanding this precaution, however, it would be well if some observer who has a large telescope should now re-examine the positions of these objects.

Researches in faint nebulae and nebulous stars appearing likely to constitute a separate and interesting branch of the astronomy of the future, it has seemed to me that the astronomers engaged in this work may like to make a careful examination of some of the stars entered in my observing-book under the category of "suspected objects." The method I adopted of insuring re-observation of these objects was by the determination, not of their absolute, but only of their relative positions,

through the agency of the larger "finder" of the great telescope. This has an aperture of five inches, a power of thirty diameters, and a field of view of seventy-eight minutes of arc. Two diagrams were usually drawn in the book for each of these objects, — the one showing the relation of adjacent objects in the great telescope, and the other the configuration of the more conspicuous objects in the field of view of the finder. Adjacent to these "finder" diagrams are the settings, — to the nearest minute of arc in declination, and of time in right ascension, — as read from the large finding-circles, divided in black and white. The field of view of the finder is crossed by two pairs of hair-lines, making a square of about twelve minutes on a side by their intersection at the centre. The diagrams in all cases represent the objects as seen with an inverting eyepiece. As the adjustment of the finder was occasionally verified, as well as the readings of the large circles, there should be no trouble in identifying any of these objects, notwithstanding the fact that no estimates of absolute magnitude were recorded. The relative magnitudes, while intended to be only approximate, are still shown with sufficient accuracy for the purpose of the research, and the diagrams are, in general, faithful tracings from the original memoranda.

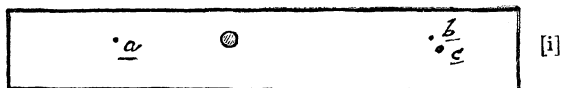
I transcribe the observing-book entire.

*Telescopic search for trans-Neptunian planet, with 26-inch equatorial.*

1877, Nov. 3.7. — Clamping polar axis, swept in declination, intending to detect planet by its supposed disk. Using power of 600, swept along plane of orbit, from long.  $155^{\circ}$  to  $166^{\circ}$ .

An object with slightly planetary look seen in  $\alpha 10^{\text{h}} 27^{\text{m}}$ ,  $\delta +10^{\circ} 0'$ .

An object (nebulous and about  $5''$  in diameter) found in  $\alpha 11^{\text{h}} 9^{\text{m}}.5$ ,  $\delta +5^{\circ} 28'$ :



It follows a star  $a 44^{\text{s}}.3$ ; and precedes  $b 69^{\text{s}}$ ;  $c 70^{\text{s}}$ .

Nov. 4.7. — Searching by same method,  $v$ ,  $148^{\circ}$  —  $163^{\circ}$ . Power 600. Soon clouded over.

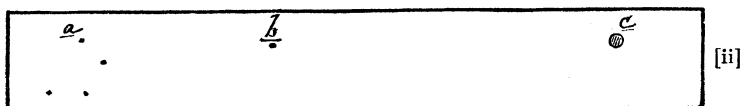
Nov. 6.7. — Attempted method of survey by recording R. A.'s of stars in narrow zones, estimating  $\delta$  and magnitude which were recorded by Townsend. Success not satisfactory — chronograph gave trouble. Then went on with sweep in declination, using power 400.  $v = 163^{\circ}$

to  $168^\circ$ . Looked again for nebulous object seen Nov. 3.7. It has not moved. It is likely a nebulous star — a glistening point of light is seen from time to time in its centre.

Nov. 7.7. — Again tried method of search by recognition of disk. Improved by having dome all dark. I set with tangent screw in declination upon successive narrow zones, and sweep in R. A. Used power 600. Success good — shall try this method further. Clouded over between 16 and 17 hrs.

Nov. 11.7. — Swept carefully between  $9^\circ$  and  $10^\circ$  of my *plan* of to-day. Used power 600.

An object suspected,  $+9^\circ 45'$ .



Object is *c*.

$$ab = 24^\circ \pm$$

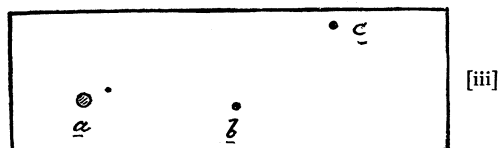
$$ac = 74^\circ \pm$$

R. A.  $10^h 19^m \pm$

I do not much believe it to be anything but a star.

**Examined again, Nov. 13.7. Object a star.**

An object *a* about equally suspected,  $+9^\circ 35'$ , R. A.  $= 11^h 1^m$ . It has a faint companion,  $p = 96^\circ$ ,  $s = 25''$ .



$ab = 12^\circ.5$ . *c* is bright star and  $2' \pm$  south of parallel of *b*.

**Examined again, Nov. 13.7. Object a star.**

Twilight, however, prevented my seeing the comes.

Iris ⑦ Nov. 11.  $a = 3^h 43^m$ ,  $\delta = +24^\circ 50'$ .

After it began to be pretty light (about  $17^h.5$ ), I tried search by clamping in R. A., and sweeping in declination, following my adopted plane of the planet's orbit.

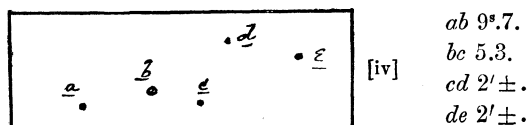
Set on  $\delta = +6^\circ.5$ .

$a = 11^h 12^m$ .

Suspected more fully an object which was too faint in the twilight to be compared with other stars near by. The instrumental position was,  $a = 11^h 20^m.5$ ,  $\delta = +5^\circ 8'$ .

Tried power 890 on it, but did not get much of a disk. Look at this again.

Nov. 12.7. — Swept (not so satisfactorily as yesterday) between  $9^\circ$  and  $8^\circ 30'$ . Seeing not first rate. Used power 600. Faint nebula (probably) as follows, at  $b$ :

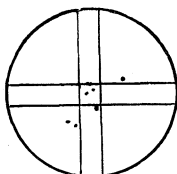


Instrumental position,  $a 10^h 43^m.5$ ;  $\delta +8^\circ 58'$ .

$10^h 43^m$ .

$+8^\circ 50'$ .

5-inch finder, thus:

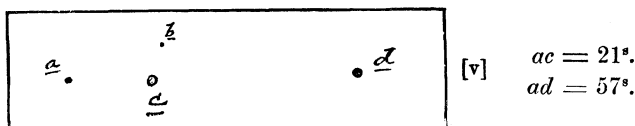


**Examined again Nov. 13.7.** Twilight prevented my seeing  $b$  and  $d$ . Look at this once more.

**Examined again Dec. 2.7.**  $b$  nebulous, but now plainly not round. Outline oblong, and jagged. It is a fixed object.

Nov. 13.7. — Good morning's work. Swept according to plan, from  $+8^\circ 30'$  to  $+7^\circ$ , only shortening the zones a little. An object which may be only a faint nebulous star at  $c$ .

Instrument  $a = 10^h 48^m$ ;  $\delta = +8^\circ 30'$ .



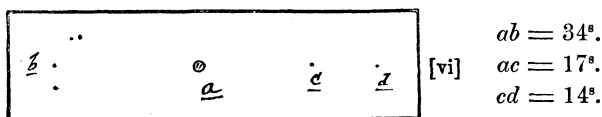
$b$  is faint companion to  $c$ , about  $2'$  distant, and  $p = 177^\circ$ .  $d$  is bright, and  $1'$  south of  $c$ .

Nov. 17.7. — Searched a short time for objects seen on the 12th and 13th. Was bothered variously, and search was ineffectual. Try again. Moonlight seems to interfere some. I think the object seen on the 13th is not now there.

Nov. 20.7. — Searched for object seen on the 12th. Either it is not now in the position then indicated, or (more likely) the full-moon

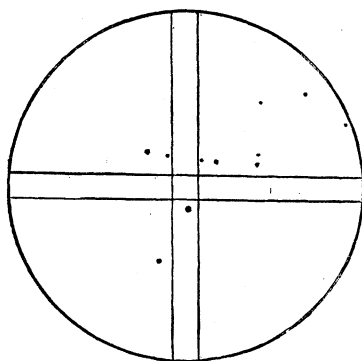
light prevents my seeing it. Try again, after the moon is out of the way — about Dec. 2.

Nov. 30.7. — Began search for object seen on 13th. Using power 600, swept carefully from  $+8^{\circ} 40'$  to  $+8^{\circ} 15'$  — zones about  $3'$  wide and  $20^m$  long. Could find nothing at all nebulous, like what I saw on the 13th. No moon present. I then tried power of 400, and at about  $16^h.5$  hit on very faint object *a*. It is not at all like a faint star; but has a disk of nearly uniform illumination. So I compare it as follows, with one star preceding, and two following:



Instrumental position  $\left\{ \begin{array}{l} a \ 10^h \ 45^m \\ \delta \ +8^{\circ} \ 36' \end{array} \right\}$  painted circles.

The stars in the five-inch finder are these:



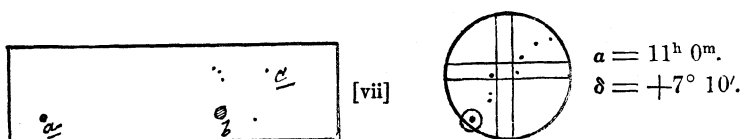
Some daylight at  $17^h.7$ , but could not then see *a*. Looked also for object seen on Nov. 12, but could not see it.

Dec. 2.7. — Settled all doubt about object seen on Nov. 12. Searched with power 400 for object seen on 13th, from  $+8^{\circ} 50'$  to  $+8^{\circ} 15'$ .

Zones  $20^m \pm$  long. Could find nothing. Either the object is not now there, or it is much less easily recognizable than I supposed

when I recorded so few stars near it. Shall now go on with the regular search.

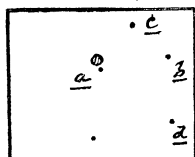
Dec. 3.7. — Object *b* not like star, though I cannot see a disk well.



$ab = 36^s.5$ . *a* is north of *b* about  $1'$ .  $bc = 4'$ .

See Dec. 11.8. Also Dec. 12.7.

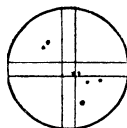
Object *a* suspected — it has a companion,  $p = 25^\circ$ .



[viii]

$$ab = 6^s.7.$$

$$bd = 2'.5.$$



$$\alpha = 10^h 59^m.$$

$$\delta = +6^\circ 42'.$$

Swept with power 400, from  $7^\circ$  to  $6^\circ$  of plan of Nov. 11.

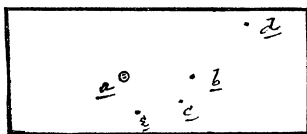
**Dec. 11.8.** — Objects *a* and companion are fixed.

**Same Dec. 12.7.**

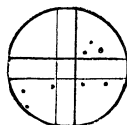
Dec. 7.7. — Came over to observatory, but found dome disabled so that I could not go on with my work.

Dec. 9.7. — Began search from  $+6^\circ$ , south. Soon clouded up. Setting for next morning is  $+6^\circ$ , exactly. Began to look for objects seen Dec. 3.7; but clouds too dense to permit their being seen. Power 400.

Dec. 11.7. — Searched with power 400, from  $6^\circ$  to  $+4^\circ 10'$ . An object *a* suspected.



[ix]



$$ab = 8^s (10^h, \text{ s. t.}).$$

$$bc = 1'.5.$$

$$ce = 3'.$$

$$bd = 5'.$$

$$ab = 8^s.4 (11^h, \text{ s. t.}).$$

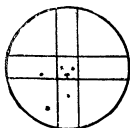
$$\alpha = 11^h 20^m.$$

$$\delta = +4^\circ 48'.$$

**Dec. 14.7.** — *a* is a very faint and small nebula. 1878, Feb. 11.7. — Did not succeed in seeing *a*.

Termination of search — a star in setting  $\alpha = 11^h 30^m$ ,  $\delta = +4^\circ 10'$ .

Finder.



Equatorial,  
Power 400.

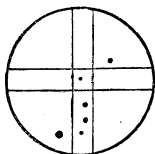




Hunted up objects seen on Dec. 3.7. The first one has moved; or, at least, pointing as then indicated with the finder, I found objects in about the position of  $a$  and  $b$ , which I suppose to be the same—though daylight prevents saying certainly. These second objects are on the same parallel, and distant  $32^{\circ}\pm$ .  $c$  was also seen.

Dec. 12.7. — Examined objects seen on Dec. 3.7. The second one, fixed. The first one—I cannot decide whether it has moved since yesterday or not, as I had no opportunity then of observing it accurately. The setting for it is, better, this:—

$$\begin{aligned} a &= 11^{\text{h}} 0^{\text{m}}. \\ \delta &= +7^{\circ} 17'. \end{aligned}$$



5-in. finder.

I now proceed to observe it accurately in R. A., and find by 14 chronographic transits that  $b$  follows  $a$  by  $31^{\circ}.92$ , at  $10^{\text{h}}.3$ , s. t.

$$b \text{ is south of } a \left\{ \begin{array}{l} 64.24 \\ 67.0 \\ \hline 2^{\text{r}}.76 = \text{.}'' \end{array} \right.$$

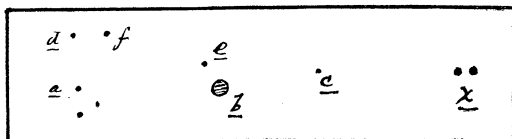
The object-glass is somewhat dewed; but I can see a companion to  $b$ , faintly—can only estimate:—

$$s = 20'' \pm.$$

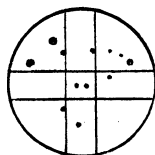
$$p = 43^{\circ} \pm.$$

Dec. 14.7. — Mean of 3 chronograph transits,  $a$  precedes  $b$   $31^{\circ}.88$ . The companion to  $b$  is visible. I conclude that  $b$  is a fixed star: I have not at any time seen the trace of a disk on it. Curiously enough, there is a group of stars nearly south of this, about  $10'$ , which have nearly the same relative positions and magnitudes (except that  $a$  is much smaller). I think I must have observed this on Dec. 3.7 though I shall not now spend time to see. I believe also that  $ab$  is more than  $36^{\circ}.5$ , somewhat.

Go on with regular search—from  $+4^{\circ} 10'$  to  $+3^{\circ} 50'$ . (Object  $b$  large and nebulous.)



[x]



$$ab = 21^s.7.$$

$$bc = 5'.$$

$$ad = 3'.$$

$$be = 2' (p = 210^\circ \pm).$$

$$a = 11^h 38^m.$$

$$\delta = +3^\circ 50'.$$

$x$  = object in centre of field of finder.

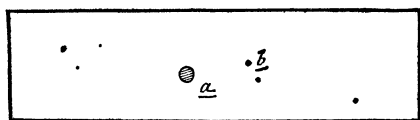
(Power 400.)

Search of this morning ends with this parallel.

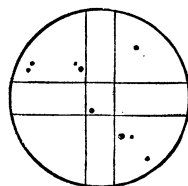
**1878, Feb. 11.7. — Object  $b$  fixed. Instead of "large and nebulous," I should now record small, quite condensed, somewhat nebulous, and faint.**

Dec. 19.8. — Bright light of moon, nearly full. Also some clouds passing. Attempted verification of object seen on 14.7. Saw the two stars  $x$ ; also  $d, f$ , and  $c$  without difficulty.  $a$ , and the two stars below it; also  $e$  and  $b$  were not visible.

Dec. 27.8. — Object  $b$ , seen on the 14th is fixed — probably a faint nebula. Going on with regular search, I suspect an object  $a$ : it has a small, but poorly defined disk.



[xi]



Power 400.

$$ab = 7^s.0 \text{ (from a few eye-and-ear transits).}$$

$$a = 11^h 56^m.$$

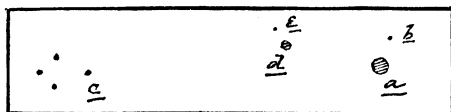
$$\delta = +2^\circ 37'.$$

Finder.

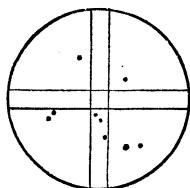
**1878, Feb. 6.6. — Object fixed.**

Search of this morning ends with this parallel. Search not wholly satisfactory, as light of moon, one day past last quarter, interfered some. Still, think I missed nothing.

1878, Jan. 2.7. — Object  $a$  seen Dec. 27.8 is fixed. Farther south I find an object which is large and nebulous. Marked  $a$ .  $d$ , small, faint, and nebulous.



[xii]



Finder.

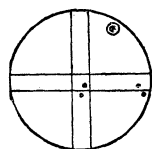
$$\begin{aligned} \Delta a. \\ ab &= 2^s.1 \text{ (} 15^h 55^m \text{)}. \\ cb &= 63^s. \\ ad &= 23^s.1. \end{aligned}$$

$b$  and  $c$  should be nearly on the same parallel.

$$\Delta \delta(ab) = 2'.5. \quad s(ed) = 1'.5.$$

1878, Feb. 6.6. —  $d$  and  $a$  fixed.

Another pair of objects :



$b$  large and nebulous.  $e$  suspected somewhat.

$a$  precedes  $b$   $0^s.2$ .

$b$  precedes  $c$   $5.7$ .

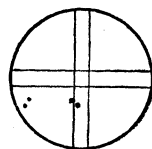
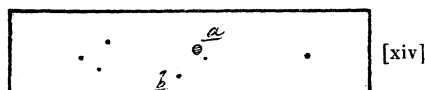
$d$  precedes  $e$   $1.4$ .

All these objects are far from my adopted plane of orbit of trans-Neptunian planet.

1878, Feb. 6.6. —  $b$  and  $e$  fixed.

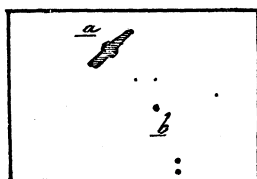
Jan. 5.7. — All four of the objects seen Jan. 2.7 are fixed. They are worth looking at again after two or three weeks, as they are near the present stationary point.

Another object,  $a$ , slightly suspected.

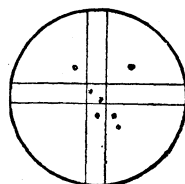


Definition so poor that it may be only a star blurred.

Finder.



$$\begin{aligned} a &= 12^h 5^m. \\ \delta &= +2^\circ 0'. \\ a \text{ precedes } b \text{ } 5^s.5 \pm \\ &\text{(at } 5^d 17^h 40^m \text{)}. \end{aligned}$$



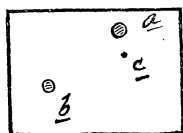
1878, Feb. 5.6. — Object fixed.

Object *a* has appearance of an elongated nebula. Beside the central condensation there is a minor and less marked one in the northern extremity (preceding).

Went on with regular search — that for this morning terminating with the above parallel,  $+2^{\circ} 0'$ .

Jan. 6.7. — At  $16^h$ , elongated object above precedes about  $5^s.1$ , by eye-and-ear transits, roughly taken. Must observe it accurately on chronograph. The central condensation is not very sharp.

Object at bottom of preceding page [xiv] does not seem to be anything but a star with faint nebulous border. In fact, the one below it (and preceding), *b*, looks exactly like it.



[xvi]

$$ac = 45'' \text{ (est.)}$$

$$ab = 1'.7.$$

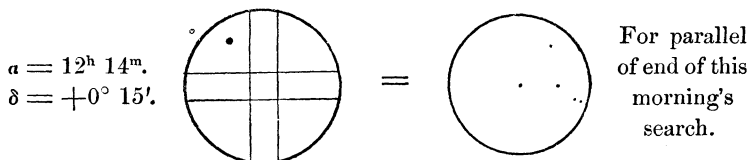
$$\angle acb = 96^{\circ}.$$

$$p \text{ (c to b)} = 125^{\circ}.$$

Look at this again, after a week or so.

#### 1878, Feb. 6.6. — Objects fixed.

Went on with regular search. Nothing suspected. Employed power 400. Search terminates with 4 mag. star in finder, thus : —



Battery out of order — cannot use chronograph. So observed object at top of preceding page [xv] by eye and ear. Mean of several transits,

$$a \text{ precedes } b \ 5^s.04. \quad 13^h \ 30^m, \text{ s. t.}$$

Measured  $\Delta \delta$  with micrometer.

Fixed wire on *a*.

Movable wire on *b*, reads  $55.62$   
 $.49$

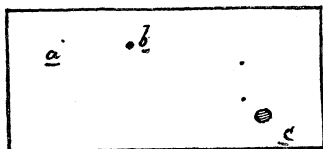
Coincidence  $64.14$ .  $55.56$   
 $64.14$

*a* south of *b* . . . . .  $8^s.58$   
 $= 85''.35.$

Jan. 11.7. — Object (elongated and nebulous) observed Jan. 5 and 6 is still at same distance as on the 6th, so far as a few eye-and-ear transits would decide. The preceding and northern "condensation," observed on the 5th, now appears as a faint star, apparently shining through that wing of the slender, elongated "nebula."

Went on with regular search, power 400. Found curious configuration of stars — 12 and 13 mag. They form a nearly perfect square (about  $35''$  on a side). On same parallel as  $\eta$  Virginis, and following it about  $10^m$ .

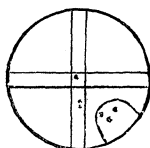
*c* suspected object — faint and nebulous — outline quite regular.



[xvii]

$$\alpha = 12^h 18^m.$$

$$\delta = -0^\circ 20'.$$



Set rough circle at  $0^\circ$  so as to bring small triangle in centre of field of finder.

*a* precedes *b*  $8^s.2 \pm$ .

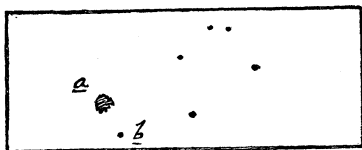
*b* precedes *c*  $13^s.6 \pm 0^s.07$  at  $17^h.5$ .

1878, Feb. 5.6. — Object fixed.

This morning's search terminates with this parallel.

Jan. 14.7. — Suspected object *c* (Jan. 11.7) fixed.

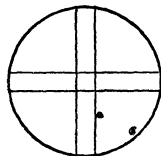
A nebulous cometary mass *a* (faint and irregular).



[xviii]

$$\alpha = 12^h 9^m.$$

$$\delta = -0^\circ 30'.$$



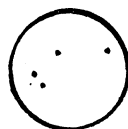
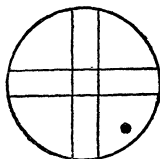
*a* precedes *b*  $4^s.1 \pm$ . Power 400.

1878, Feb. 6.6. — Object fixed.

Search ends ( $\gamma$  Virginis).

$$\alpha = 12^h 35^m.$$

$$\delta = -1^\circ 10'.$$

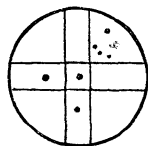


Elongated object first seen Jan. 5.7 is a nebula. I think it is Herschel (G. C. 2776).

Feb. 5.5. — Began search — finder thus: —

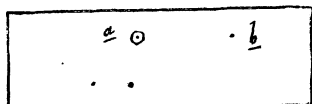
$$a = 10^h 9^m.$$

$$\delta = +13^\circ 30'.$$



Power 400.

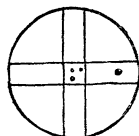
Object *a* suspected.



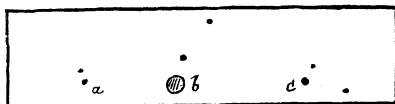
[xix]

$$a = 9^h 56^m.$$

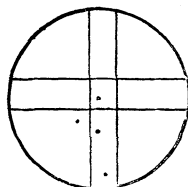
$$\delta = +13^\circ 25'.$$



$$ab = 25^s.3 \pm 0^s.1.$$



[xx]



*b* very faint and diffused.

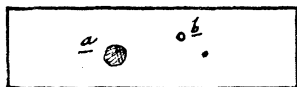
$$ab = 32^s \pm.$$

$$bc = 43^s \pm.$$

$$a = 10^h 5^m.$$

$$\delta = +13^\circ 18'.$$

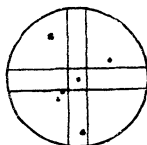
Came upon an object — finder: —



[xxi]

$$a = 10^h 3^m.$$

$$\delta = +12^\circ 55'.$$



*b* pretty bright.

*a* quite faint, and seems to have a disk.

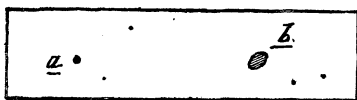
*a* precedes *b* (mean of 6 chronograph transits)  $28^s.17$  at s. t.  $11^h 12^m$ .

*a* precedes *b* (mean of 9 chronograph transits)  $28^s.35$  at s. t.  $14^h 6^m$ .

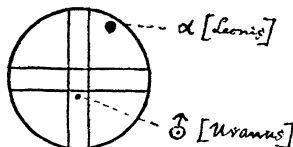
Feb. 6.5. — Object *a* (bottom of preceding page) [xxi] precedes *b*  $28^s.39$  (mean of 10 chronograph transits, at m. t.  $12^h 50^m \pm 10^m$ ).

Went on with regular search. Power 400.

Suspected object faint and diffused.

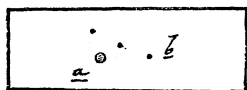


[xxii]



$$ba = 86^s.$$

Object *a* small and quite faint.

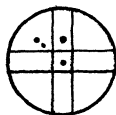


$$ab = 6^s.$$

[xxiii]

$$a = 10^h 6^m.$$

$$\delta = +12^\circ 20' -.$$



1878, Mar. 5.6. — Object fixed.

Continue search from this setting of finder — beginning with parallel of the wide pair.  $\delta = +12^\circ 8'$ .

Spent an hour or two in re-examining objects previously suspected. Notes accompany each object examined. Found all fixed — many small and faint nebulae.

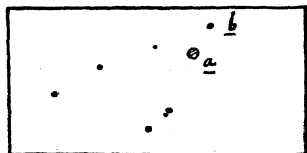
Feb. 11.6. — Object 10 lines above [xxiii], fixed — distance roughly  $6^s$ , by disappearance-transits.

Object *a* (bottom preceding page [xxi]) precedes *b*  $28^s.3$ ; (mean of two eye-and-ear transits). It still has the same appearance — very like that of a faint planet, with a small, ill-defined disk.

An hour or so in examining other objects previously suspected. Notes *loco*. Moon is beginning to interfere seriously.

Feb. 26.5. — Began search with power 400, at parallel  $+9^\circ 30'$ , going north.

Object *a* suspected — not a good disk — only regular and nebulous.



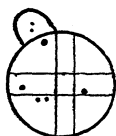
$$\Delta a.$$

$$ab = 3^s.25.$$

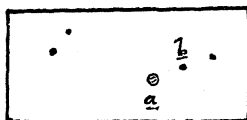
[xxiv]

$$a = 10^h 31^m.$$

$$\delta = +9^\circ 35'.$$



1878, Feb. 28.5. — Object fixed.

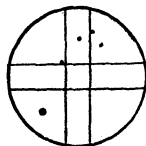


$$ab = 1'.5.$$

[xxv]

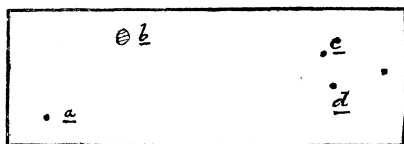
$$a = 10^h 37^m.5.$$

$$\delta = +10^\circ 45' +.$$

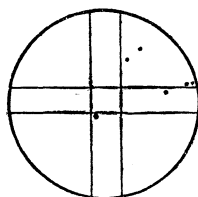


*a* very faint, and but faintly suspected.

1878, Feb. 28.5. — Object fixed.



[xxvi]



$$ab = 7^s.9 \pm 0^s.1.$$

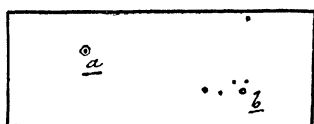
$$cd = 2^s.0.$$

$$\alpha = 10^h 30^m.$$

$$\delta = +10^\circ 55'.$$

Morning's search terminates with this parallel.

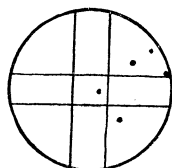
Feb. 28.5. — Going on with search. Power 400. Verified places of objects seen Feb. 26.5.



[xxvii]

$$\alpha = 10^h 15^m.$$

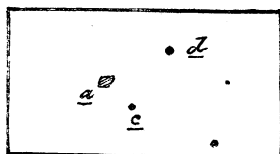
$$\delta = +11^\circ 0'.$$



$$\Delta a (ab) = 27^s.15.$$

$a$  bright and very star-like — disk slightly suspected.

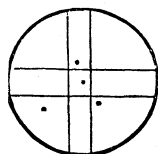
1878, Mar. 4.5. — Object fixed.



[xxviii]

$$\alpha = 10^h 30^m.$$

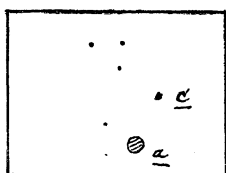
$$\delta = +11^\circ 10'.$$



$a$  very faint — could not observe transits.

$ac$  a little less than  $\frac{1}{2} ad$  or  $\frac{1}{2} cd$ .

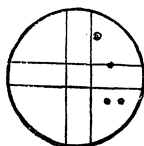
1878, Mar. 4.5. — Object fixed.



[xxix]

$$\alpha = 10^h 15^m.$$

$$\delta = +11^\circ 30'.$$



$a$  quite faint: and nebulous (regularly).

$$\Delta a (ac) = (7^s.0) ??$$

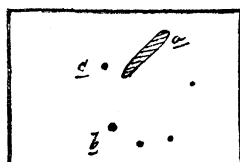
1878, Mar. 4.5. — Object (probably) fixed.



Morning's search terminates with this parallel.

1878, Mar. 4.6,  $\Delta a(ac) = 5^s.2 \pm 0^s.1$ . I feel quite sure that  $a$  has not moved: the  $\Delta a$  ( $7^s.0$ ) was put down from memory on March 2, without much hope of its being right. But, judging from the configuration, I say that  $a$  has not moved appreciably.

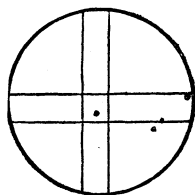
March 4.5. — Proceeded with regular search (power 400) after verifying objects seen Feb. 28.5+.



[xxx]

$$a = 10^h 26^m.5.$$

$$\delta = +11^\circ 50'.$$



$a$  like elongated nebula — rather faint. Centre of it about same R. A. as star  $b$ . I have represented it somewhat too far south — its centre should be nearer parallel of star  $c$ .

#### 1878, Mar. 5.5. — Object fixed.

Morning's search terminates with this parallel.

Put up instrument all in order at 1.45 A. M. Cahill, watchman — told him to wake me at 6 A.M.

March 5.5. — Proceeded with regular search (power 400), after verifying object seen yesterday.

Happened upon a nebulous mass — central condensation quite sharp — in  $a = 10^h 39^m$ ,  $\delta = +12^\circ 20'$ . I take it to be G. C. 2194, and so do not observe its position accurately: it is very bright.

Completed this morning the zone which fills up the gap to  $\delta = +12^\circ 20'$  (see Feb. 6.5); and went still farther north — to  $\delta = +12^\circ 40'$ .

So that the adopted plane of orbit of trans-Neptunian planet is now searched (without break) from

$$v = 146^\circ.8$$

to

$$v = 186.1.$$

Put up instrument all in order at 3 A. M., March 6, and went home at 3.45. Hayes, watchman in charge.

LAWRENCE OBSERVATORY, AMHERST, MASS.,

7 October, 1885.